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## THE DESTRUCTION OF THE VITALITY OF CYSTICERCUS BOVIS BY FREEZING

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The question as to the length of time *Cysticercus bovis* may survive after the death of its host has been quite definitely settled by the researches of Perroncito, Zschocke, Ostertag and others. Perroncito (1877) found that the cysticeri in an artificially infested calf were all dead fourteen days after the slaughter of the animal. However, Zschocke (1896) succeeded in infesting the human subject with a tapeworm by feeding five cysticeri from beef kept from fourteen to sixteen days after slaughter. No infestation followed the swallowing of five cysticeri from beef kept twenty-one days after slaughter. Ostertag (1897) examined in a thermostat a large number of cysticeri from beef kept in cold storage at temperatures above freezing for various periods of time after slaughter and concluded that the parasites are no longer capable of development on the twentieth day, although slight movements were observed in a few cysticeri as late as twenty-four days after slaughter. These results were confirmed by feeding experiments in which thirty-four persons swallowed cysticeri from beef held in cold storage at temperatures above freezing for from twenty to twenty-one days after slaughter. No tapeworm infestation resulted in any case.

The conclusions from these investigations are that a lapse of twenty-one days after slaughter is amply sufficient to insure the death of the beef cysticercus, and on the other hand that fourteen days is not sufficient, although in some cases, as determined by Perroncito in one instance, the parasites may have lost their vitality within this shorter period of time. Cognizance has been taken of these results in the meat-inspection regulations of Germany, United States and other countries, which provide that beef carcasses showing infestation with cysticeri in a certain slight degree may be passed for food after retention in cold storage for twenty-one days.

The question of the period of time *Cysticercus bovis* may survive after the death of its host having been settled, the next question which arises is whether this period may be shortened by artificial means. The means which naturally suggests itself as the least objectionable in its effects on meat and the most practicable of application is exposure to low temperatures. Reissmann (1897) has reported that beef cysticerci inserted into the depths of large pieces of meat which were then kept at temperatures of from  $-8$  to  $-10$  C. (17.6 to 14 F.) do not survive when thus exposed for three days. *Cysticercus cellulosae* appeared to be somewhat more resistant and required four days exposure before its vitality was destroyed. Prior to Reissmann, Glage (1896) noted that in the case of a measly pork ham (11 kg. in weight) which was exposed to a low temperature and solidly frozen, most of the cysticerci were still alive after two days of such exposure. As a result of several experiments Boccalari (1903) concluded that *Cysticercus bovis* and *C. cellulosae* die in four days at a temperature of from  $-4$  to  $-6$  C. (24.8 to 21.2 F.) and in six days at a temperature of from 0 to  $-2$  C. (32 to 28.4 F.).

Recent experiments by the writer on *Cysticercus bovis* have led to somewhat different results than those obtained by Reissmann and Boccalari, and in fact have shown that the exposure of measly beef to temperatures as low as 15 F. for four days is not sufficient to insure a complete destruction of the vitality of the cysticerci. In these experiments two beef carcasses, heavily infested with live cysticerci, were used. The carcasses were allowed to hang for about twenty-four hours after slaughter in a chill-room, the temperature of which was somewhat higher than the freezing-point. They were then quartered and placed in a cold-storage compartment (freezer), in which the temperature varied during the experiments between 11 and 15 F.; most of the time between 14 and 15. The temperature of the freezer was taken at four-hour intervals. The thermometer used was checked with a thermometer recently standardized by the Bureau of Standards. In the case of one of the carcasses, a quarter was retained in the chill-room, in order that check observations might be made on unfrozen cysticerci. Examination of one of the quarters of beef was made two days after it had been placed in the freezer, at which time it was found that the deeper portions of the meat had not yet become solidly frozen. All of the beef kept in the freezer longer than two days was found to be solidly frozen throughout.

Portions of one of the carcasses were removed from the freezer after a lapse of two, three and six days, respectively, allowed to thaw, and eighteen to twenty-four hours after removal dissected. The cysticerci were isolated, removed from their cysts and examined on a



warm stage kept at a temperature of 40 to 45 C. Careful observations were made to detect signs of life. If the parasite did not move and showed no response to stimulation with a needle-point it was considered dead. The heads of those cysticerci which showed no movement in the retracted condition were evaginated by pressure and carefully observed, as it was found that in such cases the head and neck sometimes still showed feeble movements, not perceptible in the retracted cysticercus.

Lack of opportunity prevented a prompt and careful examination of thirty-six cysticerci removed from the beef kept two days in the freezer, but it was observed that one of them showed definite signs of life. These cysticerci were taken from the superficial frozen portions of the meat.

Sixteen cysticerci from the beef kept three days in the freezer were examined and seven, or 44 per cent., were found to be alive.

Sixty-three cysticerci from the beef kept six days in the freezer were examined and none was found alive. Six others were removed from the same meat with special precautions to prevent possible injury. The cysts were left intact, together with a small amount of surrounding muscular tissue. These six cysticerci were swallowed by a human subject (the writer). Eighteen weeks (Sept. 23, 1913, to Jan. 29, 1914) have elapsed and no signs of tapeworm infestation have yet appeared.

Meat from the other carcass was removed from the freezer after a lapse of four, five and six days, respectively, and allowed to thaw, after which the cysticerci were isolated and examined as in the case of the first carcass.

Forty per cent. of the cysticerci from the beef kept four days in the freezer proved to be alive; that is, ten out of twenty-five examined.

Only one out of twenty-one cysticerci, or 5 per cent., was still alive in the beef kept in the freezer for five days, and this one showed such faint signs of life that it probably would have been incapable of development in the human host.

Thirty cysticerci were examined from the beef kept six days in the freezer and none showed any evidence of being alive. Five others, intact in their cysts and surrounded by small portions of muscular tissue, were swallowed by a human subject (the writer). An examination was made of twelve cysticerci from the portion of the same carcass, which had been kept since slaughter, eight days in all in an unfrozen condition, and all were found to be alive and active. Fifteen weeks (Oct. 16, 1913, to Jan. 29, 1914) have elapsed since the five cysticerci above referred to were swallowed and no evidence of tapeworm infestation has yet appeared.

From these experiments it may be concluded that if measly beef carcasses are exposed for six days to a temperature not exceeding 15 F. (—9.44 C.) the vitality of the cysticerci will be destroyed, that some may survive in carcasses exposed for five days to this temperature, though it is doubtful whether they will retain sufficient vitality to develop in the human host, and finally that a considerable proportion may survive in carcasses exposed to a temperature of 15 F. for four days or less. Though it is possible that the vitality of the cysticerci, which were observed to be alive after exposure of the infested beef to a temperature of 15 F. for four days, had been so seriously affected that they would have been incapable of producing tapeworm infestation, the fact that they were alive and active justifies the adoption of a longer period of retention when refrigeration is employed as a sanitary measure. Likewise it would seem, notwithstanding the evidently weakened condition of the only cysticercus which survived in beef exposed five days to a temperature of 15 F., that it is not justifiable to accept five days as a safe period for refrigeration, and that six days should be required until it shall be shown that a shorter period of refrigeration is fully sufficient to prevent the possibility that cysticerci present in the refrigerated meat may retain enough vitality to continue their development in the human host. On the basis of the results which have been herein recorded, an amendment to the federal meat inspection regulations has been issued providing that beef carcasses showing a certain slight degree of infestation may be passed for food if held for six days at a temperature not exceeding 15 F., as an alternative to the requirement of retention for twenty-one days. As over 40,000 beef carcasses are annually retained on account of *Cysticercus bovis* in establishments under federal inspection, this modification of the regulations will result in a considerable saving in the handling of such carcasses. Some carcasses, particularly heavy carcasses of the highest quality of beef, suffer little or no deterioration when held for twenty-one days in coolers at temperatures above freezing, and these are likely to be held in coolers as heretofore for the full twenty-one-day period. Many of the carcasses, however, which are retained on account of *Cysticercus bovis*, are of such a character that they cannot be kept unspoiled for three weeks unless they are frozen. Under the new regulations, instead of being refrigerated for three weeks, these carcasses will be held for six days at a temperature not higher than 15 F. and then released for food. The refrigeration expense will thus be greatly reduced. Only about a third as much cold will have to be produced for each carcass, and only about a third as much storage space will be required to take care of the carcasses. Heretofore at many establishments the freezers have been more or less constantly

congested with retained carcasses, and at times more carcasses have been retained than there was room for in the available freezer space. Such conditions will be greatly relieved by the new regulations.

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## SUMMARY OF TWO YEARS' STUDY OF INSECTS IN RELATION TO PELLAGRA

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With the growing interest in pellagra, following the authoritative recognition of its presence in the United States in 1907, the study of its etiology was taken up by various investigators and the several theories of causation were subjected to close scrutiny.

Prominent among these theories was that of insect transmission, first advanced by Sambon, who limited this function to the species of blood-sucking gnats comprising the genus *Simulium*.

The importance of the disease and the possibility of such a factor in its causation, led the Bureau of Entomology, late in 1911, to undertake an investigation of the subject in South Carolina, to which locality attention had been directed by the state authorities. The writer and W. V. King were, early in 1912, assigned by Dr. L. O. Howard, Chief of the Bureau of Entomology, United States Department of Agriculture, under the direction of Mr. W. D. Hunter of the Bureau, to investigate the possible relation of insects to pellagra and to gather such data as might serve to indicate whether there was ground for the assumption that blood-sucking or other arthropods were involved in the transmission of the disease in that region.

In June, 1912, the Thompson-McFadden Pellagra Commission of the Department of Tropical Medicine, New York Post-Graduate Medical School, established its laboratory and began its field work at Spartanburg, in Spartanburg County, S. C.

Through the courtesy of Capt. J. F. Siler, Medical Corps, United States Army, and with the approval of Dr. L. O. Howard, Chief of the Bureau of Entomology, the representatives of the Bureau were enabled to cooperate with the commission and to study the possible relation of insects to the causation of pellagra.

The work undertaken under these auspices consisted of a general study of such insects as appeared after a careful review of the situation to present possibilities in this connection. The species which seemed worthy of consideration were studied as to biology and habits, with special reference to the epidemiology of the disease and to the habits of those classes of the population in which appear the great mass of the cases of pellagra.

The homes of pellagrins were studied, together with the sanitary condition of their surroundings, and especially careful attention was given to the mill villages in which occur many cases of the disease.

Collections of insects were made and no effort was spared to come to an unbiased conclusion in the case of each species studied. Careful elimination of such forms as failed to meet our conception of the characteristics required was effected on the grounds set forth below.

Field work was continued until October 15, and the details of the work was published as a progress report. In April, 1913, the work was again taken up. In June, a hospital for pellagrins having been established in Spartanburg, we were afforded facilities for more elaborate laboratory studies, including the attempted transmission of pellagra to monkeys by the bites of blood-sucking insects. The details of the latter work were carried on by Mr. King and will form the basis for a later report.

As a basis for our work it was necessary to assume that pellagra is an infectious disease and that it is capable of transmission by blood-sucking insects, but it must be well understood that no positive convictions were entertained and the possibility only of such conditions is implied. In weighing the evidence as to the involvement of each insect we were impelled to apply Knab's postulate in this connection, and I shall quote its substance:

In order to be a potential transmitter of human blood-parasites, an insect must be closely associated with man and normally have opportunity to suck his blood repeatedly. It is not sufficient that occasional specimens bite man as, for example, is the case with forest mosquitoes. Although a person may be bitten by a large number of such mosquitoes, the chance that any of these mosquitoes survive to develop the parasites in question (assuming such development to be possible), and then find opportunity to bite and infect another person, are altogether too remote.

The results of the work of 1913 were, in the main, corroborative of those of 1912, but further studies by the commission have broadened the view and introduced some new elements.

Two mill villages in counties adjacent to that of Spartanburg are equipped with an effective water-carriage system of sewage disposal. It was found that in these villages, pellagra has failed to obtain a foothold, although introduced a number of times. In the town of Spartanburg, also, there appears to be a correlation between the absence of sewers and the prevalence of pellagra.

The studies have also brought out the fact that a close domiciliary connection appears to exist between cases originating in 1912 and 1913, and older or antecedent cases; that is, the cases developing in these years, in the mill villages under consideration, which show a close household association with antecedent cases, form a large percentage of

the cases for three years. Cases which have been in less close association with older cases, such as neighbors living next door or across the street from them, form a much smaller percentage of the total. Those living at greater distances are, in some villages, wanting, the total number of such cases being very small.

That this phenomenon indicates infectiousness is so clear as to amount almost to a demonstration.

The prevalence of *Pediculus capitis* seems to be somewhat greater than we had supposed and we are led to believe that our previous views did not reflect the actual condition. This was due largely to the improved facilities for observation at our command in 1913 and partly also to the overcoming of reticence on the part of pellagra patients and their families.

The evidence gathered does not materially alter our views regarding the agency of these insects, but the fact that we had underestimated their abundance suggests the desirability of further work along this line in 1914.

The insects on which our studies were especially concentrated were the ticks, lice, bedbugs, roaches, horseflies (Tabanidae), fleas, mosquitoes, buffalo gnats (*Simulium*), houseflies and the stable fly (*Stomoxys calcitrans*).

The ticks (family Ixodidae, the only family of the group represented in South Carolina) can be safely excluded by reason of their biting habits and life history. The fact that most ticks of this family require three hosts during the life cycle, remain attached during each stage, drop to the ground at its completion and re-attach to another after molting, precludes their incrimination. So rarely could a tick remain attached to a human host a time sufficient for its engorgement and the completion of the current stage of its development, that its chances for becoming infective and living to transmit its infection would be practically *nil*. It must be borne in mind that we are dealing with a disease which shows no evidence of the existence of reservoirs of its virus among the lower animals. Ticks are not a serious pest in Spartanburg County, and those suffering most from pellagra, the home-keeping adult females and young children, are those least exposed to the bites of ticks.

The head louse was excluded by us in 1912 because its prevalence seemed inadequate to the dissemination of a disease with the epidemiologic characteristics of pellagra. The occurrence of a considerable number of cases among persons whose circumstances and habits should safeguard them from attack by *Pediculus* is opposed to the agency of the insects.



The relative incidence in males and females is not satisfactorily explained by their incrimination and the distribution of cases in the individual foci of the disease does not appear, in our opinion, strongly to indicate a flightless carrier with a human vehicle.

Notwithstanding our misconception as to the prevalence of the species, additional facts will be necessary to place it among the probable transmitters of pellagra.

In large cities, with congested populations, unhygienic surroundings and abundance of *Pediculus*, pellagra does not obtain a foothold in spite of the introduction of cases of the disease.

The bedbug, *Cimex lectularius*, although very abundant and universally distributed, when considered as a possible carrier of pellagra, does not account for certain marked characteristics of the disease. Its association with man is of the closest nature and the conditions under which a large class of pellagra suffers live, favor in high degree its indiscriminate attack on all members of the household generally. But the indiscriminate character of its attentions is the strongest argument against its incrimination.

Although the approximate ratio of infection of females to males, as a whole, in the United States is as 3 to 1, we find that among adults, nine women are victims of pellagra to every man affected. The ratio is much too high to be accounted for by an assumed selectiveness on the part of the bug by its opportunity for attack on either sex, which must be practically equal, or by a supposititious immunity of the male sex to pellagra infection.

Roaches, though common throughout the region, are negligible in connection with our subject unless the disease is found to be transmissible by means of contaminated foodstuffs. Should this be the case their rôle must still be subordinate to that of the housefly.

The family Tabanidae, which includes the well-known horse flies, should be mentioned because of their blood-sucking habits and the fact that at certain times and in some localities they attack man with a degree of frequency and persistence. These attacks are, however, desultory and have no part in the essential economy of the flies. In Spartanburg County, flies of this group were found to be far from common, and this fact together with their irregular attack on man, and an entire lack of association with him, serves to exclude them conclusively from consideration.

When attention was given to the fleas of the region, a somewhat unexpected condition was found to exist. Superficially considered, these insects might be thought to present possibilities in connection with pellagra transmission, and great care was taken to collect all possible information regarding them as well as material for study. So

uniform were negative statements as to attacks by them that we were forced to believe that as pests of human beings in the locality, fleas play but a small part. This is the less remarkable in view of the fact that we were unable to collect the human flea, *Pulex irritans*, at any time. The cat and dog fleas as well as a few chicken fleas, *Echinophaga gallinacea*, were collected from various hosts and a number of rats, captured in the town of Spartanburg, were infested by the European rat flea, *Ceratophyllus fasciatus*, and a considerable number of the Indian rat flea, *Xenopsylla cheopis*. A few specimens of *Ctenopsylla musculi* were also obtained.

The sharply defined host habits of most fleas render the species which are characteristic parasites of cats, dogs, rats, etc., rarely troublesome to man under normal American conditions. When conditions are favorable for the inordinate propagation of the cat or dog fleas or an epizootic decimates the host species, as in plague, this may occur, but under ordinary circumstances these fleas will remain on human beings a comparatively short time and transference from man to man probably occurs but seldom. Transmission of human disease by the same channel would similarly be unlikely to occur. In addition, the sex incidence of pellagra cannot be satisfactorily explained by the incrimination of these insects.

The only mosquitoes of the region studied which justify consideration in connection with possible pellagra transmission are the two house species, *Aedes calopus* and *Culex quinquefasciatus* (fatigans). The latter species is nocturnal in habit, and its incrimination is incompatible with the sex incidence of pellagra.

While the yellow-fever mosquito is emphatically a day mosquito, its occurrence in Spartanburg County is by no means constant or regular. It should be noted that in spite of its presence in the town of Spartanburg, the species was not taken in the country districts or at points remote from railroad communication with its more southern and regular habitat. In the summer of 1912 no individuals of this species were observed, while in 1913, from June 1, the *Stegomyia* was a common and troublesome pest in Spartanburg. At the time of its appearance in 1913, the seasonal epidemic of pellagra was well advanced and the disease was showing great activity. On no accepted theory as to its period of latency, whether of short or long duration, can this species be incriminated in view of these phenomena. In spite of its day-biting habits, therefore, *Aedes calopus* must remain excluded as a causative agent.

Our studies in 1912 convinced us that there was little evidence to support the incrimination of any species of *Simulium* in South Carolina in the transmission of pellagra. Reviewing the group as a whole, we

find that its species are essentially "wild" and lack those habits of intimate association with man which would be expected in the vector of such a disease as pellagra. Although these flies are excessively abundant in some parts of their range and are moderately so in Spartanburg County, man is merely an incidental host, and no disposition whatever to seek him out or to invade his domicile seems to be manifested. Critically considered, it is nearer the fact that usually man is attacked only when he invades their habitat.

As our knowledge of pellagra accumulates, it is more and more evident that its origin is in some way closely associated with the domicile. The possibility that an insect whose association with man and his immediate environment is, at the best, casual and desultory, can be active in the causation of the disease becomes increasingly remote.

Our knowledge of the biting habits of *Simulium* is not complete, but it is evident, as regards American species at least, that these are sometimes not constant for the same species in different localities. Certain species will bite man freely when opportunity offers, while others have never been known to attack him. To assume that the proximity of a *Simulium*-breeding stream necessarily implies that persons in its vicinity must be attacked and bitten is highly fallacious. In Spartanburg County attacks by *Simulium* seem to be confined to the immediate vicinity of the breeding-places. Our records and observations, exceedingly few in number, refer almost exclusively to such locations. Statements regarding such attacks, secured with much care and discrimination from a large number of persons, including many pellagrins, indicate conclusively that these insects are seldom a pest of man in this county. A certain number of the persons questioned were familiar with the gnats in other localities, but the majority were seemingly ignorant of the existence of such flies with biting habits. This is especially striking, in view of the fact that the average distance of streams from the homes of the pellagra cases studied was about 200 yards, many being at a distance of less than 100 yards, and that 78 per cent. of these streams were found to be infested by larval *Simulium*. Such ignorance in a large number of persons cannot be overlooked and indicates strongly that our belief in the negligible character of local attacks by *Simulium* is well founded.

In localities infested by "sand-flies," mosquitoes, etc., these pests are always well known and the ignorance described above is very significant.

Such positive reports as we received nearly always referred to bites received in the open, along streams, etc., and observations made of their attack were of those on field laborers in similar situations. Males engaged in agricultural pursuits are almost exempt from pellagra



in Spartanburg County. During the season of 1913, in some two or three instances, observations were made of the biting of *Simulium* and some additional and entirely credible reports were received. These observations and reports were under conditions identical with those referred to in the reports of 1912 and confirm the conclusions based on the observations of that year. I would repeat with emphasis that it is inconceivable that a fly of the appearance and habits of the prevalent species of *Simulium* could be present in such a region, especially about the haunts of man and attack him with sufficient frequency and regularity to satisfactorily account for so active and prevalent a disease as pellagra without being a well-known and recognized pest.

In connection with the conditions in the Piedmont region of South Carolina, it may be well to cite the results of a study of those in the arid region of western Texas.

In May, 1913, in company with Capt. J. F. Siler of the Thompson-McFadden Pellagra Commission, I visited the region of which Midland in Midland County is the center. This region is very dry and totally devoid of running water for a long distance in every direction. The only natural source of water-supply, a few water holes and ponds, were visited and found to be of such a nature that the survival of *Simulium*, far less its propagation in them, is absolutely impossible. The nearest stream affording possibilities as a source of *Simulium* is 60 miles away, while the average distance of such possibility is not less than 100 miles.

Artificial sources of water-supply were also investigated carefully and were found to offer no opportunity for the breeding of *Simulium*.

At Midland the histories of five cases of pellagra were obtained, which gave clear evidence that this place or its immediate vicinity was the point of origin. Persons of long residence in the country were questioned as to the occurrence of such flies as *Simulium* and returned negative answers. These included a retired cattle owner, who is a man of education and a keen observer, an expert veterinarian stationed in the country who has the cattle of the country under constant observation, and a practical cattle man, manager of a ranch and of wide experience. The latter had had experience with "buffalo gnats" in other localities (in the East) and is well acquainted with them. His close personal supervision of the cattle under his charge, makes it practically certain that he would have discovered these gnats had they been present in the country.

At the time the study was made, *Simulium* was breeding and active in the adult state in the vicinity of Dallas, Texas, in the eastern part of the state. We have here a region in which cases of pellagra have originated, yet in which *Simulium* does not and cannot breed. Dr.

Samson has suggested that in the absence of *Simulium* certain midges of the family Chironomidae may assume the function of transmitting pellagra.

In the course of our field work, especial attention was paid to small flies of all kinds, and although the conditions were favorable for the discovery of any blood-sucking *Chironomidae* or other midges, none were collected during the two seasons spent in the field from early spring until late fall.

The reports opposed to the frequent attacks of *Simulium* may be taken as applying also to the present group. At the risk of repetition, I would note that in the coast region of South Carolina, "sand-flies" are abundant, and are only too well known to the inhabitants.

In the course of the work of 1912, we became convinced that *Stomoxys calcitrans*, the stable-fly, which had been regarded by us merely with suspicion, was an insect which merited the closest study in connection with pellagra transmission. It is practically cosmopolitan in distribution and is found at considerable altitudes and in high latitudes. It is an abundant species almost everywhere throughout its range, and in many places is a very serious pest of domestic animals. Under favorable conditions, there are sometimes outbreaks of this fly which cause the death of many animals and untold worry and suffering to all live stock within its influence. Primarily and by preference, it preys on the larger domestic animals and breeds in their excreta. Nevertheless, it attacks man frequently and with persistence, although with some irregularity, depending to a certain extent on the presence or absence of the animals on which it usually feeds and seemingly also on weather conditions. Its association with domestic animals brings it also into somewhat close association with man, and it readily takes up a more or less prolonged residence in and about human habitations. Ample corroboration of these statements occurs in the literature of the species.

The longevity of *Stomoxys calcitrans* in nature is not known with accuracy, but experimentally the fly has been kept in confinement and fed artificially for a period of eighty-nine days. This record was obtained by W. V. King in the course of pellagra transmission experiments in 1913. The average life of the flies used in the work was much less than this, and it is highly probable that the natural life is also much shorter than three months. This species frequently attacks several hosts during the taking of a single meal, and the habit is of importance in connection with disease transmission, especially when mechanical transference of an organism is possible. The habit seems to be less a matter of choice than because of the frequency with which it is dislodged by the animal attacked. When this occurs before the

appetite is satisfied, another spot on the same animal or another is selected and a fresh bite inflicted. Experimentally fed flies usually, when undisturbed, remain attached until the completion of the meal, unless the part selected is unproductive, when the proboscis may be withdrawn and another chosen. There is great variation in the time required for complete engorgement, depending apparently on the blood-supply of the skin at that point. On man, if applied to the lower extremities, a full meal may be taken in three or four minutes, while not infrequently the fly remains as much as fifteen minutes before voluntarily withdrawing the proboscis.

In passing, it may be noted that *Stomoxys* is purely predatory in its feeding habits; it is not attracted to such substances as the nasal secretions of animals nor to carrion or offensive substances other than the excreta of the larger herbivorous animals. It is reported to breed in the feces of hogs, but in my own experience I have not observed this. I have not seen them apparently attracted to hoggens nor attacking hogs, though they doubtless do so on occasion. This species is distributed throughout the state of South Carolina, and in Spartanburg County it is very abundant. In all the cities and towns of the state it is present in large numbers and in the rural districts its abundance is even greater. Mill villages in or about which cattle are invariably kept are infested by large numbers of these flies and the usually unscreened houses are quite regularly entered by them. That the inhabitants are frequently bitten cannot be doubted as the overwhelming numbers of reports indicate. Some individuals can almost always be found in or about all houses in the mill villages of the region, and a favorite resting place is about the porches on which much time is spent by the inhabitants.

Many reports were received of attacks of *Stomoxys* on persons engaged in milking cows, and this duty falls largely on the female members of the household. A milk cow is kept by about one family in three, and the milking is done at the home of the owner to which the animal is brought, or in some mill villages, the cattle are excluded and milked and cared for in the common pasture.

When it is recalled that a high percentage of cases of pellagra occur among those who spend a large proportion of their time in or about the home, the habit of *Stomoxys* in frequenting not only the interiors of dwellings, but those parts of their exteriors which are occupied by the inhabitants is important.

Statements regarding the biting of man by *Stomoxys* were so universal in our territory and were so amply confirmed by our own experience and observations, it must be admitted that the habit is frequently practiced. It should be emphasized that man is not attacked



with the frequency and persistence displayed by such insects as the house mosquitoes, and it is not impossible that the distributional picture of pellagra may be largely accounted for by this fact. Given even a moderate degree of infectiousness and such a transmitter as the common species of *Culex*, the spread of the disease could hardly fail to be much greater and more rapid than it is known to be.

In addition to the reports received as to the biting habits of this fly, our own observations and the published statements regarding it, it seemed desirable to obtain, if possible, definite proof of the frequency with which human beings are attacked. By examination of the stomach contents of a large number of flies and determination of the species to which the host belonged it was hoped that some conclusion could be reached. The method adopted was the application of the precipitin reaction to the blood ingested by flies captured in localities where there would be reasonable opportunity for the selection by them of human hosts. More than 600 dissections were made, but the results in only about 200 of these are at present available. Of these, 109 were taken under circumstances which implied a fair chance for the fly to have recently attacked man, that is, in or about occupied dwellings, stores, etc. Six of these, or  $5\frac{1}{2}$  per cent., gave a positive human reaction.

In collecting the material no effort was made to select weather especially favorable for attack on man by the flies, and the days when captures were made it covered quite a wide range of meteorologic conditions.

The number of human reactions obtained may seem small, but that at one period of a few minutes at each spot, such a number of flies were found, weather disregarded, to have recently fed on human beings, appears to indicate a rather free exercise of the habit. Were it possible to capture and test all flies within the bounds of a mill village for a twenty-four-hour period, and should this ratio hold, the result from our point of view would be startling. As a matter of fact, the percentage would almost certainly fall below that mentioned and yet would, with equal certainty, represent a large number of bites with their attendant possibilities of disease transmission.

A point of interest in this series is that two of the six flies had fed on man only, three had fed also on cattle, while one gave a reaction with the sera of ox, horse and man. The blood of bovines only was determined in the stomachs of 80 per cent. of this series; of equines only, in but 6.4 per cent., while bovine and equine reaction was obtained in 7 per cent. The latter results are strongly corroborative of the observations on interrupted feeding by this species.

It has been suggested that the bite of *Stomoxys* is so painful to human beings that but a small percentage of the flies attempting to draw blood from them could succeed in doing so, and that almost all

would be driven off without attaining their object. Even if this were true it has been shown that trypanosomiasis may be communicated by the mere picking of the skin by an infected *Glossina*, even when the fly is immediately removed and no blood drawn. It may be assumed that if the parasite of pellagra is a protozoon and *Stomoxys* its carrier, that the same means may be effective.

It cannot be doubted that, almost invariably, the stable fly is driven from its human host when the pain of the bite becomes noticeable. To ascertain whether blood, even in small quantity might not have, by that time, been drawn, a series of tests was made in which clean-bred *Stomoxys* were allowed to bite selected parts of the bodies of several individuals. Such parts of the extremities as are frequently exposed were chosen and single flies confined in flat-bottomed shell-vials 25 by 100 mm., the end covered with gauze were applied to the bare skin, or in some instances the fly was allowed to bite through the stocking which covered the part. No hesitation was usually shown by the fly in proceeding to secure its meal, whether the skin was covered or bare. When the tube had been applied the subject was instructed to report the instant the first indication of pain was felt, the tube being then immediately removed and the fly dissected. Thirty-three flies were thus used, the forearm, lower leg and ankle being selected for the infliction of bites. In eleven instances, or 33 per cent. of the tests, before pain was felt, an amount of blood was drawn which ranged from one-third to a full engorgement, and in five, or almost half, a full meal was taken. In three cases on two subjects no sensation was felt at any time and the fly completed its feed and withdrew the proboscis without the knowledge of the host that a bite had been inflicted.

In many cases, the insertion of the proboscis and the early part of the process of drawing blood causes no sensation. At times when the fly is partially engorged the proboscis is thrust deeper or its position slightly changed when a more or less severe prick is felt. Were the bite incurred under natural conditions the victim would naturally assume that this was the moment of attack. The wary fly, in spite of partial engorgement, is usually able to withdraw the proboscis and avoid a hasty, ill-directed slap.

In the painless bites it is evident that anesthetic areas of the skin were selected, and analysis of my notes shows that one was inflicted one inch in front of prominence at lower end of tibia, one on external aspect of lower leg near median line and 6 inches above the ankle, the third at about the same point but 2 inches higher. This was on a different subject from the preceding.

Two other full engorgements, in which some pain was felt, were drawn from 1 inch posterior to the prominence at lower end of tibia, the other from 1 inch in front of the prominence. No painless bites

were inflicted on the forearms, but five blood-meals, ranging from one-third to two-thirds the full feed, were drawn from approximately the same areas as those already indicated.

It is of common experience that the stocking-clad ankle and parts of the leg adjacent thereto are favorite points of attack by *Stomoxys calcitrans*, even in the case of persons who are habitually shod. As far as these experiments go, they indicate that, from such parts of the body, an amount of blood may be drawn which by all analogy should be amply sufficient to cause the infection of the fly with any parasite present in it and capable of causing such infection.

House-flies are everywhere excessively abundant in Spartanburg County, houses are generally unscreened and if pellagra should prove to be communicable through contamination of food, utensils, etc., this ubiquitous pest will probably be found to play an important part in the spread of the disease.

Blow-flies are prevalent, and though far less numerous than house-flies, are, from their predilection for human excreta as a breeding-place, likely to be individually very active in such dissemination.

The facts which have come to light regarding sewage disposal by means of efficient water carriage and its seeming effect on the occurrence of pellagra, gives additional interest to the consideration of *Musca domestica* in this connection. Our present knowledge does not, however, justify a discussion of these facts or an attempt to determine whether the presence of sewers and the failure of pellagra to become active are merely coincidental and have no direct correlation; whether their effect is indirect or whether the presence of this system is a prime factor in the control of the disease. If the latter is the case, the incrimination of the house-fly seems certain.

#### CONCLUSION

Our studies have led us to believe that ticks, bedbugs, mosquitoes, fleas, horseflies, and, in the absence of further and more incriminating evidence, the lice, may be dismissed from consideration as transmitters of pellagra; that there is not only insufficient evidence to incriminate flies of the genus *Simulium*, but much evidence directly opposed to such incrimination and that the biting stable-fly, *Stomoxys calcitrans*, shows in marked degree those characteristics of distribution, habit and association with man which would pre-eminently fit it to be the vector of pellagra if transmission of the disease by a blood-sucking insect is shown to be possible.

If pellagra is found to be an intestinal disease of bacterial origin, house-flies and others of similar habits will in all probability be found to be an active factor in its causation.



## VARIATION IN OXYURIAS: ITS BEARING ON THE VALUE OF A NEMATODE FORMULA \*

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One of the most difficult problems in zoologic science is the classification of round worms. Authors and lecturers, after a carefully outlined and definitely arranged discussion of trematodes and cestodes, are compelled to consider nematodes in a somewhat desultory and inaccurate fashion. Two reasons for this may be given, the greater being the apparent lack of a basis for determining the phylogeny of the major groups, a condition with which we are not at present concerned. The other obstacle is the difficulty of differentiating between species and uncertainty as to the value of different kinds of taxonomic characters. The multitude of synonyms for many of our common insects is a sore point among entomologists, but nematohelminthologists have great difficulty in deciding that any particular name should be relegated to the synonymy.

In the absence of definite structural differences, Dujardin in 1846 found himself compelled to give a few measurements of the length, breadth, tail, etc., of the species which he described. This method was further applied by Eberth in Germany and Bastian in England, followed by Bütschli and others. Finally, in 1890, N. A. Cobb arranged a "nematode formula" which he has applied in all his subsequent work. This formula shows two kinds of measurements: first, the length of the worm in millimeters; second, the percentage of that length which is represented by the distance from the anterior end of the worm to (*a*) the base of the pharynx, (*b*) the nerve ring, (*c*) the cardiac constriction, (*d*) the vulva, and (*e*) the anus; and also the width of the body at each of these points. He uses the formulae of different species, both in descriptions and in keys for identification.

Cobb has described something over one hundred species of free-living round worms of the family Anguillulidae and has always worked out and stated the formula. As there are at present no other scientists making a specialty of this family, it would be unfair to emphasize the fact that, in the quarter century since the description of this formula, it has been used only by its originator. There are,

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\* Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 31.

however, many helminthologists concerned with parasitic Nematoda where the obstacles of classification are equally great. Some of these have seen the possibilities of such a formula, but a real doubt as to its value has prevented them from adopting it. Until the following questions are answered, one must feel that energy and time invested in descriptions of this nature are not well employed:

1. Can the formula be applied at all to the majority of parasitic species?

2. Is the camera-lucida method of measurement sufficiently accurate for such a purpose?

3. Are the relative proportions of the different organs constant within a single species?

Cobb has not discussed these points in his published papers. He has applied the formula to very few parasitic species and apparently not at all to the difficult ones. He has published no warnings concerning the undoubted distortions caused by the varying tilt of the mirror, or the part of it from which a particular organ is reflected. In no case, so far as I am aware, does he give any indication that he has measured more than one individual of each species. This is especially noticeable in view of the fact that he must have had numerous specimens of some forms and that general attention has been called to this lack in as prominent a place as the Cambridge Natural History.

At the suggestion of Prof. Henry B. Ward of the University of Illinois, the writer recently undertook an investigation of the variation in the proportion of the organs. Incidentally, fragmentary observations on the other two questions are reported.

Cobb's measurements were made on camera-lucida drawings of cleared worms and this procedure has been modified in only one particular. Most of the worms measured by the writer were studied merely in formalin, only about one-fourth having been dehydrated and cleared in carbol xylol. None were mounted in balsam but all were studied under a cover-glass. The greatest care was used to avoid errors due to faulty technic, such as would be caused by accidental differences in the position of the camera-lucida. The effect of transferring the specimens from formalin to the clearing agent was not determined but is probably slight. The first fourteen worms whose measurements are reported in the table were cleared.

The first species of which drawings were made with a view to measurement was the hookworm, *Necator americanus* Stiles. Unfortunately, this is bent in two planes, the head being hooked at a right angle to the general body curvature. In addition, the males, of which most of the available material consisted, have the anus at the tip of

the body. The body wall is so opaque that locations of internal structure are difficult to determine, and the writer was unable to discover any method of making the nerve ring visible. For these reasons the conclusion was reached that the formula could not be satisfactorily used on these worms and work on the species was abandoned.

Accurate measurement of larger worms, such as Ascaridae, was out of the question, no apparatus adaptable to this use being available or on the market. These facts partially answer the first two problems involved, it being clear, first, that the Strongylidae, especially the hookworms, do not readily lend themselves to classification by this means; second, that the camera-lucida method of measurement now in vogue is not applicable to worms exceeding 1 cm. in length. Possibly the latter obstacle may still be overcome by the use of special apparatus if the formula proves its worth in other points.

The department of zoology then secured about one hundred specimens of *Oxyurias vermicularis* Linn., the pinworm of man. These were all from one host, living in a rural locality in Kentucky, and were all voided at the same time. It soon became clear that, among the parasitic genera, *Oxyurias* is ideal for such work. The specimens were preserved in formalin, and at first the vulva could not be located with certainty, but clearing in carbolxylol corrected that difficulty. As a consequence, the writer was able to make a rigorous test of practically all of Cobb's characters except the position of the nerve ring, which could not be determined, owing to the preservative. It may be noted in passing that the nerve ring is often difficult to locate, one of Cobb's largest papers (1893) omitting that character in the formulae of one-third of the species. Cobb gives (1890a) the formula for a young individual of *O. vermicularis*, but its immature condition invalidates any possible comparison with the results given here.

The purpose of this work was not to examine critically the particular points located by Cobb, but to ascertain the extent to which the proportions of the worm were constant, and the parts which undergo the greatest variation. The results should be of interest, both to parasitologists and to systematists, regardless of their relation to this particular formula or group.

The unit of measurement used was 1 per cent. of the length of the individual. Measurements were made on this basis from the anterior end (1) to the caudal margin of the cephalic swelling; (2) to the beginning of the esophageal bulb; (3) to the cardiac constriction; (4) to the vulva; (5) to the anus; (6) to the anterior and posterior limits of the internal reproductive organs. The width at each of these points was also determined. Finally, the total length of the worm was calculated. Fifty-two individuals were measured, but



in most of them one character or another was so indefinite that the writer did not feel justified in recording what appeared to be its location. This was especially true of the vulva, invisible in uncleared material.

The following table gives the measurements of each worm studied. In the first column is the arbitrary number of the specimen. The second gives the length of the worm in millimeters. The figures in all the other columns indicate the percentage of the length of the worm from the cephalic end to that particular point, the columns being numbered as in the last paragraph. Column 6, however, shows only the interval occupied by the reproductive organs. "L" indicates length and "W" width. Finally, for each of these *characters*, there is recorded (a) the average, (b) the number of specimens on which the character was determined, (c) the "standard of variation," (d) the maximum and (e) the minimum measurement found, and (r) the range. The average is the sum of all the measurements divided by (b). The standard of variation was calculated by the well-known formula,  $\left( \sigma = \sqrt{\frac{\sum (x-f)^2}{n}} \right)$ ,  $x$  being the deviation of a class from the average, and  $f$ , the number in the class. The range is merely the maximum, (d), minus the minimum, (e).

Attention should be called to the fact that results (a) and (c) were calculated from measurements to the second decimal place. In order to limit space it was thought desirable to omit the second place in the printed record. This will explain any slight discrepancies which might confuse, should these results be checked over. The lack of value of the second or even the first decimal place is discussed in a later paragraph.

The average length of the body of this species is 7.39 mm. The range is about one-fourth of the maximum length. As the curve is normal, the total range in the species is probably not much greater than this.

1. The *external cephalic swelling* is peculiar to the species studied and is a secondary development of no great definiteness or importance. The curve of the variation in its length is an irregular one and far from the normal type. It will be noted that the range is over two-fifths of the maximum, and that the standard of variation is 0.397 per cent., or about one-ninth of the maximum. In view of the nature of this feature, considerable variation was to be expected.

2. The *esophageal bulb* marks a distinct division of the alimentary canal and is bounded by two definite constrictions. The esophagus, which leads from the mouth to this bulb, is straight or slightly bent, in no case being sufficiently curved to draw the bulb out of its position. Variation is from 8.3 per cent. to 12.1 per cent., a range of 3.8 per cent.

TABLE OF MEASUREMENTS

No.	L in mm.	1		2		3		4		5		6	
		L	W	L	W	L	W	L	W	L	W	Interval	No.
1	7.05	2.2	2.6	9.5	4.8	11.7	5.3	24.1	6.4	77.5	3.1	69.5	1
2	7.37	2.4	2.0	10.0	3.5	12.3	3.7	31.4	5.2	78.8	3.2	61.9	2
3	7.97	2.7	2.1	9.7	4.2	12.2	4.4	30.1	5.3	78.5	2.0	62.1	3
4	7.51	2.3	2.0	9.9	3.1	12.5	3.9	26.8	3.3	78.2	2.3	...	4
5	7.51	2.0	2.0	9.4	3.6	12.1	3.4	26.8	3.6	78.2	1.9	...	5
6	7.75	3.4	2.1	9.4	2.8	12.1	3.4	31.9	4.5	79.3	3.1	...	6
7	6.87	2.9	2.1	10.1	3.9	13.4	4.3	...	...	74.5	2.1	60.3	7
8	7.20	3.3	1.8	10.9	2.9	13.4	3.1	35.6	...	78.8	2.1	...	8
9	8.35	3.0	1.7	9.1	2.9	11.4	3.2	24.7	...	78.9	2.5	...	9
10	7.74	2.4	2.3	9.2	4.2	11.2	4.5	29.2	5.6	74.8	3.2	73.3	10
11	6.41	2.4	2.5	...	4.6	...	...	23.1	5.9	...	...	...	11
12	6.93	3.2	2.1	...	4.3	...	...	27.3	7.4	...	...	...	12
13	7.64	2.5	2.1	...	4.3	...	...	3.3	3.8	...	...	...	13
14	8.10	2.9	2.3	10.0	3.9	13.4	4.4	78.0	...	79.2	2.0	67.5	14
15	8.15	2.6	2.1	11.1	3.9	11.1	4.1	...	...	76.1	3.1	66.3	15
16	7.17	2.3	2.3	10.5	4.8	13.1	5.4	...	...	76.8	3.0	64.8	16
17	6.45	3.1	1.8	8.7	2.9	10.8	3.0	...	...	79.8	2.3	58.8	17
18	6.45	3.1	1.8	8.7	2.9	10.8	3.0	...	...	76.3	2.6	64.7	18
19	7.32	2.5	2.5	...	...	...	...	...	...	76.1	3.2	60.2	19
20	7.32	3.0	2.4	10.1	4.0	12.5	4.5	...	...	...	...	...	20
21	8.60	2.7	1.8	9.1	3.4	11.6	3.9	...	...	76.6	3.2	...	21
22	6.67	2.3	2.6	12.1	4.9	14.2	5.2	...	...	78.5	2.8	...	22
23	6.67	2.3	2.6	12.1	4.9	14.2	5.2	...	...	78.5	2.8	...	23
24	7.03	2.6	2.8	11.1	4.5	12.9	4.8	...	...	77.5	3.5	...	24
25	6.85	2.4	2.6	11.2	5.8	13.4	6.3	...	...	77.5	3.5	66.8	25
26	7.46	3.1	2.1	9.9	3.2	12.2	3.5	...	...	80.6	3.6	37.5	26
27	7.71	2.4	2.2	10.4	4.8	...	...	...	...	74.2	3.6	63.8	27
28	6.67	3.4	2.4	11.4	3.9	14.4	4.5	...	...	...	...	51.0	28
29	7.02	3.6	1.6	10.3	2.4	13.0	2.4	...	...	77.6	2.1	...	29
30	6.50	...	...	8.3	2.8	10.4	2.9	...	...	...	2.1	...	30
31	7.53	3.2	1.6	9.0	2.8	10.4	2.9	...	...	81.4	2.1	...	31
32	7.89	3.4	2.3	7.3	2.3	11.2	2.5	...	...	79.2	2.1	...	32
33	7.89	2.6	2.3	6.7	3.9	12.5	3.2	...	...	79.2	2.9	34.1	33
34	6.74	2.9	1.9	6.0	2.6	11.0	3.1	...	...	79.2	2.0	...	34
35	7.35	5.2	1.9	9.2	3.7	11.1	3.9	...	...	79.5	2.8	52.2	35
36	8.37	2.9	1.9	9.6	3.3	12.2	3.9	...	...	75.5	3.1	59.2	36
37	7.52	3.3	2.0	10.0	3.1	12.4	3.3	...	...	76.7	...	73.9	37
38	6.94	...	...	7.47	2.4	11.9	2.5	...	...	77.2	...	34.9	38
39	6.94	...	...	7.47	2.4	11.9	2.5	...	...	77.2	...	...	39
40	7.25	...	...	9.8	2.6	12.9	2.8	...	...	75.8	3.1	38.2	40
41	7.25	...	...	9.8	2.6	12.9	2.8	...	...	78.3	2.4	46.2	41
42	8.00	2.8	2.0	11.0	3.6	13.8	3.4	...	...	78.0	2.3	42.5	42
43	7.96	2.7	1.9	8.5	2.8	11.1	3.3	...	...	80.2	2.5	30.5	43
44	8.35	2.6	2.4	10.0	4.5	12.3	4.9	...	...	77.0	3.3	40.6	44
45	7.03	2.1	1.6	9.6	3.2	13.0	3.4	...	...	81.2	2.3	47.4	45
46	7.40	2.9	1.8	9.5	2.9	11.7	3.1	...	...	80.2	2.3	...	46
47	7.96	2.9	2.1	8.9	3.0	11.9	3.1	...	...	78.8	3.0	...	47
48	7.20	3.0	1.8	9.2	2.7	11.7	3.1	...	...	80.5	2.0	...	48
49	8.50	2.7	1.7	8.6	2.9	10.6	3.3	...	...	78.4	2.3	...	49
50	...	2.4	2.2	9.3	4.0	11.5	4.4	...	...	76.8	3.2	63.5	50
51	...	2.4	2.2	9.3	4.0	11.5	4.4	...	...	76.8	3.2	63.5	51
52	...	2.4	2.2	9.3	4.0	11.5	4.4	...	...	76.8	3.2	63.5	52
53	...	2.4	2.2	9.3	4.0	11.5	4.4	...	...	76.8	3.2	63.5	53
(a) No. spec.	7.39	2.8	2.1	9.8	3.2	12.2	3.9	27.6	5.8	78.2	2.7	56.1	Av.
(b) No. spec.	49	48	48	48	49	47	48	13	11	48	46	30	σ
(c) σ	584	397	314	714	878	896	...	337	757	178	468	...	M
(d) M	8.60	3.7	2.8	12.1	5.8	14.4	6.3	33.6	7.4	81.4	3.6	75.1	m
(e) m	6.41	2.1	1.6	8.3	2.3	10.4	2.4	23.1	4.5	74.2	1.9	37.5	M-m
(r) M-m	2.19	1.6	1.2	3.8	3.5	4.0	3.9	10.5	2.9	7.2	1.7	37.6	

\* See text.

The magnitude of the range and of the standard of variation is striking.

3. The *cardiac constriction* is the caudal limit of the esophageal bulb, which occupies from 2 to 3 per cent. of the length of the worm. The distance of this constriction from the mouth varies from 10.4 to 14.4 per cent., and the range, 4 per cent., is about two-sevenths of the maximum. This range overlaps about one-sixth of all the species Cobb has described in the papers at hand.

4. Only thirteen individuals were studied in which the vulva could be located, it being invisible in the opaque formalin material. In the cleared specimens, the range in its position was about one-third of the maximum distance from the mouth. The standard of variation, 3.37 per cent., is over four times that of any of the first three structures.



Fig. 1.—*Oxyurias vermicularis* Linn. Specimen No. 2; lateral aspect of cleared worm. 1-6, the structures and distances measured in this paper; for explanation see text, and table opposite.

5. The anus is usually located in the caudal fourth of the body, its position varying from 74.2 to 81.4 per cent., a range of 7.2 per cent. The standard of variation is 1.78 per cent., or midway between those of the last two structures. Some reliance, therefore, can be placed on measurements of the location of the anus.

6. In the use of the formula, the interval occupied by the reproductive organs is given in an approximate and general way. Cobb usually uses a multiple of 10 per cent. to express this distance. Even this approximation, however, appears to be of no value in *Oxyurias*. In some cases these organs reach from a point near the mouth (5.7 per cent.) to a point behind the anus (86.9 per cent.), often obscuring the latter's position. In other specimens they have shrunk to a small size or are undeveloped. The interval occupied varies from 37.5 to 75.1 per cent., a range of 37.6 per cent. Such a condition makes the recording of this interval in the specimens at hand when a species is described a waste of labor.

While measurements of the lengths of different structures vary independently of each other, this is not true of the widths at different points. For this reason separate discussions of the latter are not necessary. In almost all cases, the range in widths is approximately equal to, or greater than, the width of the most slender worm studied. So few specimens were measured at the vulva that the range there is



not as great as it should be, neither the slimmest nor plumpest worms having been measured at this point. Taking the width at the cardiac constriction as typical, we find a variation of from 2.4 to 6.3 per cent. The latter worm was particularly contracted, however, the normal range being from 2.4 to 5.4 per cent., as shown by the curve of variation.

If structures were correlated with each other, considerable reliance could be placed on the body proportions in spite of the individual variation. It was hoped that a study of correlation would yield results which would assist in the interpretation of the relation between an unnamed specimen and a given formula. The attempt to find such assistance, however, must be considered a failure.

Correlation diagrams were made to show the relation of the width of the body to the length of the esophagus, the length of the alimentary canal to the length of the esophagus, the relation of the position of the vulva to that of the anus and to that of the cardiac constriction, etc. In no case was there the least indication of correlation, except between the length of the esophagus and the position of the cardiac constriction. As the esophageal bulb which separates these is small and rather constant in size, this fact can hardly be called a true correlation.

Much of the importance of a study of variation in its relation to classification depends on the differences between the various species with the group concerned. Thus, if all Nematoda had an esophagus about one-eighth the length of the body, had the vulva placed within the cephalic third, and the anus near the beginning of the caudal fourth of the total length, a variation no greater than occurs in *Oxyurias* would make the measurement method valueless in identification. The formulae of about one hundred species described by N. A. Cobb were, therefore, examined in order to determine the variation within the class. In some cases curves were plotted.

This examination showed an ideal condition for such a scheme. A curve including the formulae of the described species is similar to a long, low mountain range. All possible changes in the proportions seem to have been observed. As a result, the range of each of the characters given above covers only one-fifth to one-tenth of the described species. In some cases it is less than that. For example, the vulva, in the eighty-five species whose descriptions happen to be before me at the moment, varies from 20 to about 80 per cent. in position. Of these, only five species are between the maximum and minimum found in the specimens of *Oxyurias* reported in this paper. Forty of them, however, or nearly half, are between 45 and 55 per cent., a range less than that in this species. The fact, therefore, that the range appears unimportant in this case seems to be an accident of the species chosen.

In tables for identification, Cobb has used such characters as "Tail 15 per cent.," as opposed to "Tail 20 per cent.,"; or "Body slender (little more than 2.6 per cent.)" in opposition to "Body not so slender (3 per cent. or over).". In these and many other places the difference specified is less than the range in this one species.

In general, the variations recorded here may be due to two causes: (a) varying state of contraction owing to chemical technic, conditions of killing, etc., and (b) ordinary fluctuating variations. General body contraction would not affect the positions of the organs and can scarcely account for differences in length percentages. On the other hand it would have an important effect on the width. Thus the length percentages, depending largely on fluctuating individual variations, are not correlated with the widths, most of which are determined by the state of contraction. The impossibility of securing uniform contraction makes it necessary to consider width measurements unreliable.

In the practice of identification of specimens two advantages may be claimed for a formula. In the first place it is an abbreviated record of what would be a long description. This advantage cannot be gainsaid and is the principal source of the strength of the "nematode formula." In the second place a comparison of the formula of a specimen at hand with those of a series of descriptions might aid in identification. This is the advantage which has been emphasized too much. The following are the formulae of a few of the specimens of *Oxyurias vermicularis*:

No. 1.	2.2	9.5	11.7	24.1 <sup>70</sup>	77.5	7.05 mm.
	2.6	4.8	5.3	6.4	3.1	
No. 2.	2.4	10.0	12.3	31.4 <sup>62</sup>	79.5	7.37 mm.
	2.0	3.5	3.7	5.2	3.2	
No. 7.	2.9	10.9	13.4	? <sup>80</sup>	74.5	6.87 mm.
	2.1	3.9	4.3	?	3.1	
No. 26.	3.1	9.9	12.2	? <sup>87</sup>	80.6	7.46 mm.
	2.1	3.2	3.5	?	3.6	
No. 42.	2.8	9.0	11.1	? <sup>80</sup>	81.2	8.05 mm.
	2.0	2.9	3.2	?	2.4	

These figures do not refer to the exact points used by Cobb, but the principle is the same. If the species had been described from No. 7 and that formula given as typical, it is doubtful whether it would aid in naming No. 26 or any of the others.

## CONCLUSIONS

The proportionate size of the organs in *Nematoda* is an important factor in their identification and should be stated in any description of a new species.

The locations of the cephalic parts of the alimentary canal tend to vary from 1 to 4 per cent., about one-third of the maximum, in *Oxyurias vermicularis*.

The location of the vulva probably varies at least 15 per cent. in a long series of individuals.

The location of the anus varies over 7 per cent., or about one-third of the length of the tail.

Variations in width are so great that some individuals are over twice as wide as others.

The length of the body of some individuals is one-third greater than that of others.

The use of the formula is likely to yield more confusion than assistance. It is impossible to indicate the observed range, and without that the numbers are meaningless. Carrying the measurement to one-tenth of 1 per cent., gives an appearance of accuracy which does not exist. The formula is likely to result in the multiplication of so-called species without a proper basis for their separation.

A species should not be described as new on account of a deviation from the proportions of known species unless that deviation is great and fundamental. The space occupied by the reproductive organs should not be considered, and little dependence should be placed on the width of the body. From four to ten individuals should always be studied and the observed range recorded. In this way the varying proportions of the different species can be used in the identification of collected specimens. An individual should never be identified, however, on the basis of the formula alone or of the proportions alone.

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## OBSERVATIONS ON THE EGGS OF ASCARIS LUMBRICOIDES

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The appearance of the ova of *Ascaris lumbricoides* as seen in fresh feces is so well known to physicians and zoologists that description is unnecessary. Occasionally, however, ascarid eggs are found which differ so widely from the normal egg of *Ascaris lumbricoides* as to cause considerable confusion on the part of observers, and may even be so misleading in appearance as to be attributed to another species. One of these atypical forms, the unfertilized egg of *Ascaris lumbricoides*, first reported by Miura and Nishiuchi (1902), is by no means rare, and is usually seen in the feces of persons infested with female parasites only (Fig. 1).

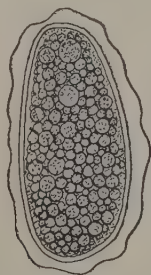


Fig. 1.—Unfertilized egg of *Ascaris lumbricoides*. After Miura and Nishiuchi, 1902.

Another atypical egg, differing from the normal egg only in size, has an exceptionally long major axis, while its width is no greater than that of the average egg, thus giving it a narrow elliptical form instead of the broad oval of the average egg. A sample of feces received from Florida contained numbers of eggs of this form, no eggs of average size being present. In this case the variation from the normal egg was so marked that it was only after having observed similar eggs known to have come from *Ascaris lumbricoides*, I could be certain of the identification. Although not reported in the literature, except for a brief note by the writer (Foster, 1913), this type of ascarid egg is apparently not rare. Drs. Stitt and Garrison, in conversation with the writer, reported seeing this atypical form in feces in Manila, while Dr. Stiles told the writer that he had seen several cases while engaged in hookworm work in the Southern states. The appearance of the

elongated egg contrasted with the normal egg is shown in Figures 2 and 3.

As the result of the measurement of over 200 eggs, half of which were derived from dissections of ascarids from man and half from ascarids of pigs, I find that there is no sharp demarcation between the excessively long egg and the average egg, but specimens can be found making a complete series. By averaging all eggs having the same

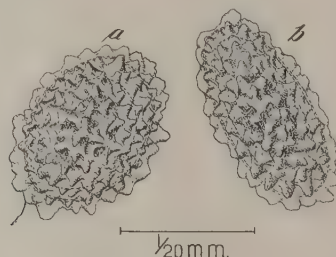


Fig. 2.—Superficial view of eggs of *Ascaris lumbricoides*. *a*, normal egg; *b*, elongated form.

length but different diameters, and arranging the results in the order of increasing length, it was found that the diameter remained fairly constant as the length of the egg increased. It follows as a corollary

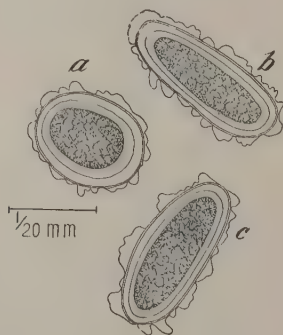


Fig. 3.—Eggs of *Ascaris lumbricoides* seen in optical section. *a*, normal egg; *b* and *c*, elongated forms.

that as the length of the eggs of *Ascaris lumbricoides* increases, the ratio of the diameter to the length steadily decreases. This rule was found to apply both to those eggs derived from ascarids from swine and to those from man. There are of course many slight exceptions to this rule, but if a sufficient number of eggs are measured to serve as

a fair basis of comparison, it will be seen that but little variation is found in the diameter of the eggs measured, while the length may vary throughout a range of 51 microns between the shortest and longest egg. When ratios are considered, instead of actual measurements, the exceptions to the corollary of the rule are very few, since individual variations are largely neutralized when expressed in terms of relative values.

The accompanying diagram (Fig. 4) shows how little variation is seen in the diameter of ascarid eggs, compared to the great variation in length. In the left-hand column, representing measurements of ascarid eggs from swine, there is a variation of 29 microns between the maximum and minimum length, although both extremes have the same diameter, which is only 7 microns less than the average diameter of all eggs measured. In the right-hand column, representing the longest and shortest egg seen in ascarids from man, there is a difference of 51 microns between the maximum and minimum lengths, while the diameter of the longest egg is actually 8 microns less than that of the shortest egg and is 12 microns less than the average diameter of all eggs measured.

The fact that all eggs, no matter what their length, have a fairly uniform diameter, would seem to be based on some morphologic structure of the female genital tract. If at some point in their development, the eggs, while still in a plastic condition, were forced lengthwise through a narrow lumen admitting only one egg at a time, we should expect to find all the eggs of a given worm having approximately the same diameter. It is evident that this modification cannot take place in the vagina, for although eggs usually pass out of the vagina in single file, dissection of the uterus shows the extremely long eggs and average eggs all having approximately the same diameter, in the proximal portion of the uterus before the eggs have passed through the vagina. Besides, the muscular wall of the vagina will expand to accommodate itself to the different diameters of the eggs rather than force them to conform to its own diameter, since the chitinous shell allows of very little if any compression. The modifying influence, if any such is present, must therefore be exerted at some point in the genital tract before the egg receives its shell, or while in the process of shell formation. As Leuckart (1867) calls attention to the fact that eggs in the posterior uterus before their shells are fully formed have approximately the same diameter though varying in length, it occurred to the writer that this modifying influence might take place as the eggs pass from the receptaculum seminis, the region immediately posterior of the uterus, into the uterus. The receptaculum seminis is separated from the uterus by a narrow sphincter-like constriction described by



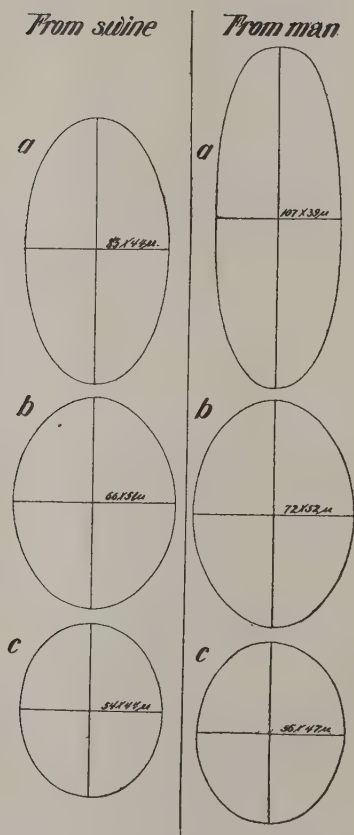


Fig. 4.—Diagram based on measurements of over 200 ascarid eggs from man and from swine, illustrating the principle that the diameter remains fairly constant as the length of the eggs increases. *a*, eggs of maximum length, from swine and from man respectively; *b*, eggs of average length; *c*, eggs of minimum length.

Leuckart (1867) and at this point the eggs are still plastic, as they do not receive their shells (according to Blanchard, 1888) until the eggs have traversed the posterior half of the uterus. Cross-sections of this sphincter, however, show that its lumen, while considerably narrower than the preceding or subsequent parts of the genital tract, is sufficiently large to allow many eggs to pass through at one time. The writer has examined cross-sections of the entire posterior half of the uterus without finding any place where the eggs when in a plastic condition would be subjected to pressure tending to give them a uniform diameter.

While the uniform diameter of eggs from the same worm may be explained by some such morphologic modification as suggested above, it is harder to explain the fact that eggs from different worms varying greatly in size, have approximately the same diameter. It is hardly reasonable to assume that the lumen of the genital tract in different worms would have approximately the same diameter at the same place, for since the external measurements of different adult individuals is subject to great variation, we should expect and in fact do find, corresponding variations in the measurements of the internal organs.

Table of measurements of eggs of *Ascaris lumbricoides* from man and from swine, arranged in order of decreasing length, to show that as the length decreases, the width remains constant or slightly increases. Measurements in microns. Each set of measurements represents the averages of five individual eggs from the same worm. In those cases where the measurements have the same length but different widths, the corresponding ratio is the ratio of the average width to the given length.

TABLE 1.—FROM SWINE			TABLE 2.—FROM MAN			TABLE 3.—COMBINED FROM ONE AND TWO		
Length	Width	Ratio	Length	Width	Ratio	Length	Width	Ratio
73.0	56.5 }	72.1	87.5	49.0	56.0	87.5	49.0	56.0
73.0	49.0 }		78.0	46.5 }	63.5	78.0	49.5	63.5
70.5	51.5 }	71.3	78.0	51.5 }		75.5	57.5	76.2
70.5	49.0 }		78.0	50.5 }	76.2	73.0	54.0	74.0
68.0	56.5 }	81.3	75.5	57.5 }		71.5	55.5	77.6
68.0	54.0 }		73.0	56.5 }	75.3	71.0	51.5	72.5
68.0	56.5 }	76.5	73.0	54.0 }		70.5	51.0	72.3
66.0	50.5 }		71.5	55.5 }	77.6	69.0	49.0	71.0
65.5	49.0 }	81.0	71.0	51.5 }	72.5	68.0	53.0	77.9
65.5	54.0 }		70.5	51.5 }	73.0	66.0	50.5	76.5
65.5	56.5 }	69.7	69.0	49.0 }	71.0	65.5	51.0	77.9
64.5	45.0 }		68.0	51.5 }	73.4	65.0	54.0	83.1
63.5	47.5 }	72.6	68.0	49.0 }		64.5	49.0	76.0
63.5	45.0 }		65.5	48.5 }	74.0	63.5	49.5	78.0
62.5	52.5 }	84.0	65.0	54.0 }	83.0	62.0	51.0	82.3
62.0	49.0 }	79.0	64.5	52.5 }	81.3	61.0	47.5	77.9
61.0	47.5 }	77.8	63.5	59.5 }	73.2	56.5	46.5	82.3
56.5	46.5 }	82.3	63.5	46.5 }				
			62.0	53.0 }	85.4			

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## DR. NOTT'S THEORY OF INSECT CAUSATION OF DISEASE

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The danger in using isolated sentences from an article as a basis for interpreting the author's theories, is generally recognized, but sometimes the most careful workers fall into the trap. Once the mistaken interpretation is published, it may be copied over and over again until it rises to the dignity of a dogma.

A striking illustration is afforded by the practical unanimity with which writers on the subject of insects and disease credit Dr. Josiah Nott with being the earliest to formulate definitely the theory of mosquito transmission of yellow fever.

Nuttall, in his classic monograph "On the Rôle of Insects, Arachnids and Myriapods as Carriers in the Spread of Bacterial and Parasitic Diseases" (1899), states: "In 1848, Nott of New Orleans published an essay on yellow fever, in which he refers to malaria *as if the mosquito theory had already been advanced*, and he gives grounds for his belief that the mosquito also gives rise to yellow fever."

The original publication was not accessible to Dr. Nuttall, who was forced to depend on an abstract furnished by Dr. Isadore Dyer of New Orleans. Following Nuttall, almost every writer on the historical aspect of the theory of insect transmission of disease, especially yellow fever, refers to Nott's theory, and some who have evidently seen and hurriedly read the original, quote specific statements which seem to indicate clearly the intent of the argument.

Dr Nott's scholarly paper on "The Cause of Yellow Fever" was published in the *New Orleans Medical and Surgical Journal*, vol. iv, in March, 1848. A cursory reading of it, in the light of present-day knowledge, affords ample indication that he believed in the insect transmission not only of yellow fever, but also of malaria and various other diseases. For instance, one could hardly draw any other conclusion from reading such isolated statements as:

"The morbid cause of yellow fever is not amenable to any of the laws of gases, vapors, emanations, etc., but has an inherent power of propagation, independent of the motions of the atmosphere, and which accords in many respects with the peculiar habits and instincts of insects.

"There are even perfectly authenticated instances where one side or end of a ship has suffered severely from the disease while the other was entirely free from it. We can readily believe that certain insects which are endowed with unaccountable instincts and habits, might attack a part of a ship, of a

tree, of a wheat or cotton field, but we cannot imagine how a gas could be turned loose on one side of the cabin of a vessel and not extend to the other.

"It would certainly be quite as philosophic (as the malarial theory) to suppose that some insect or animalcule hatched in the lowlands, like the mosquito, after passing through its metamorphosis takes flight and either from a preference for a different atmosphere, or impelled by one of those extraordinary instincts which many are known to possess, wings its way to the hill top to fulfil its appointed destiny."

Explicit as these statements seem, they can be interpreted only when we remember that Nott wrote at a period before Pasteur and Koch had completely revolutionized the ideas of medical men regarding the causation of disease, and that he was in reality presenting a masterly argument in favor of a germ theory of disease. No one can read the entire article, in its proper historical setting, without realizing that Dr. Nott used the term "insect" to denominate micro-organisms, and that his explicit references to true insects were merely for the purpose of illustrating the propagation, methods of development and habits of the invisible "insects" or "animalcules" whose existence he postulated.

He did speak of "the perfect analogy between the habits of certain insects and yellow fever," but he had no more intention of urging that the disease was mosquito borne than that it was carried by the aphids, Hessian flies or cotton worms that he also cites for illustration.

If, after reading the full article, additional evidence is desired, it is furnished in a conclusive manner by going still further back. Dr. Nott takes pains to explain that "there is no novelty in the doctrine of the insect or animalcule origin of disease" and states that "the most elaborate and ingenious article I have met with is that in Sir Henry Holland's Medical Notes, "On the Hypothesis of Insect Life as a Cause of Disease."

On referring to that interesting book, printed in 1839, we find that Dr. Holland raises the question as to "what weight we may attach to the opinion that certain diseases, and especially some of epidemic and contagious kind, are derived from minute forms of animal life, existing in the atmosphere under particular circumstances."

His use of the term "insect" is illustrated by the statement:

"It is only of late that the wonderful eye of the microscope has clearly disclosed to us that vast domain of life to which the infusoria belong; a new world which might have remained forever as much hidden from our sense and knowledge as the *invisible forms of insect life*, of which the hypothesis before us presumes the existence.

"If existing, the same analogy will lead us to other inferences, not less probable, as to those habits and instincts, in which they may be presumed to have affinity for the known insect genera. Such are their frequent sudden generation, at irregular and often distant periods, under certain circumstances of season or locality, or under other conditions, less obvious to apprehension. Secondly, the diffusion of swarms, so generated, and with rapidly repeated

propagation, over wide tracts of country, and often following particular lines of movement. To which general inferences may be added another (resting on analogy, though of less explicit kind), namely, that certain of these animalcule species may act as poisons, or causes of disease.

! "Whatever is true as to the habits of insects obvious to our senses, is likely to be more especially so in those whose minuteness removes them further from observation." (Italics mine.)

It was to the support of this hypothesis of causation of disease by micro-organisms and this alone, that Nott brought a wealth of observations on yellow fever and malaria, and he deserves full credit for the logical manner in which he analyzed and presented his data.

## RHABDITIN

CONTRIBUTION TO A SCIENCE OF NEMATOLOGY

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Rhabditin is the term applied by the writer to an organic substance, the type form of which is found crystallized in brilliantly doubly refractive spheres arranged in a definite way in the cells of the intestine *Rhabditis monhystera* Bütschli, and other nematodes, in whose metabolism it plays an important rôle.

Rhabditin crystallizes under the life influences of *Rhabditis monhystera* into spheres, about 1 to 3 microns in diameter, which are rather slowly soluble in water, rapidly so in alkalies and acids—in the latter without effervescence—and are insoluble or but very slowly soluble in alcohol, glycerin, xylol and oils. The aqueous solution gives no precipitate with barium chlorid or barium hydrate. The crystals do not change essentially in optical properties (do not melt or dissolve) when the nematodes are fixed in boiling absolute alcohol.

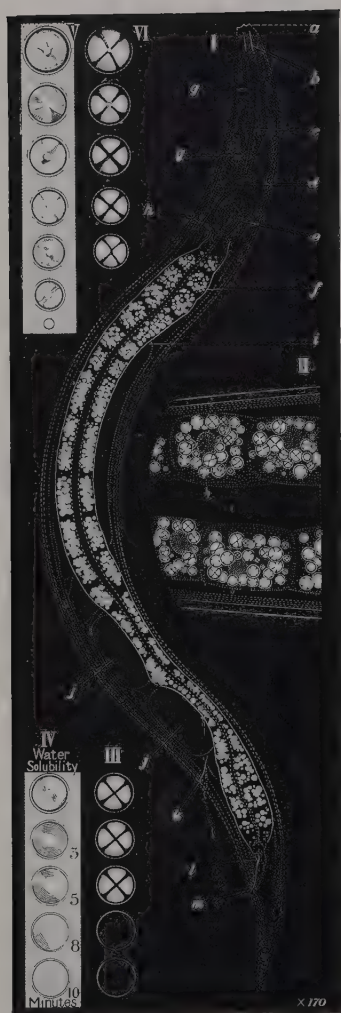
When disintegrating in water the internal parts of the spheres first dissolve, leaving in the course of five to thirty minutes shells (plasts?) which are not doubly refractive, and which stain readily and strongly in solution of gentian violet, less strongly in aqueous safranin. The crystals, when freshly removed from the tissues of the nematode and placed immediately in the violet, while strongly stained externally, do not appear to be stained in the internal doubly refractive part, the "maltese cross" of which appears brilliant and unstained when viewed with crossed Nichols. Rhabditin does not stain in iodine-potassium-iodide solution.

In a microscopic test the crushed bodies of *Rhabditis monhystera* reduced Fehling's solution, and it seemed probable that rhabditin was the main if not the sole reducing agent.

When the spheres are undergoing brownian movements they prove to be doubly refractive in every view, though the maltese cross occasionally "blinks," as if in one particular direction this property is less pronounced.

In *Rhabditis monhystera* the crystals of rhabditin are arranged in relatively large groups round the centrally located nuclei of the intestinal cells, and sometimes constitute a large fraction of the mass of the cells. They are absent, or infrequent, in the initial intestinal cells





Female *Rhabditis monhystera* Bütschli viewed with polarized light. I. Lateral aspect. II. Section of worm more highly magnified, showing intestinal cells, their nuclei, and crystals of rhabditin. III and IV. Crystals of rhabditin in process of solution in water. Note that the maltese cross remains undiminished in brilliancy even when a large proportion of the rhabditin has been dissolved, indicating that the solution takes place from the center outward. V and VI. Crystals of rhabditin showing the comparative appearance of crystals of various size when seen without polarized light.

a, lips; b, pharynx; c, median bulb; d, nerve-ring; e, cardiac bulb; f, intestine; g, posterior portion of esophagus; h, excretory pore; i, flexure in ovary; j, eggs; k, vulva; l, rectum; m, anus.



— the few immediately behind the cardia. They may be found in each of the other cells of the intestine, but are then likely to be a trifle less numerous in the final cells. They do not occur in any other cells of the body. In some other species they occur less generally, sometimes only in a part of the intestine, and sometimes as "double" spheres.

When the bodies of *Rhabditis monhystera* are incinerated no trace of rhabditin remains; when the bodies containing a large amount of rhabditin are burned in a Bunsen flame in front of the spectroscope, only a very faint flickering sodium band is to be seen, indicating the absence of the earthy constituents that might be expected in certain excretory salts, for example, calcium.

From the foregoing tests it will be seen that the present indications are that rhabditin is a carbohydrate, though it seems out of harmony with this supposition that the crystals do not decrease materially in number or size when the nematode containing them is placed on a starvation basis in distilled water for seven days. During this time other granules in the same cells, believed to be fatty substances, disappear. Its isolation in sufficient quantity for more complete tests will be a difficult matter.

Rhabditin occurs in embryos, even very young ones, in comparatively early stages of their segmentation, and the future intestinal cells may sometimes be distinguished from other cells by what appear to be exceedingly minute crystals of rhabditin.

Rhabditin has been noted by various investigators under the name of "granules," for the most part merely so indicated in drawings, without comment, except where indicated merely as a means of species characterization.

With the crystals of rhabditin there often occur other granular bodies of a different nature.

## EXPERIMENTAL INGESTION BY MAN OF CYSTICERCI OF CARNIVORE TAPEWORMS

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Having experimentally eaten the larvae of dog tapeworms on two occasions, I undertook to look up the literature on this subject in connection with the ingestion of *Cysticercus pisiformis* to check the frequently quoted record of *T. pisiformis* from man. I find that there are more cases of the sort than I had supposed, so I have collected these cases in connection with a recent similar case of my own.

*Taenia pisiformis*, under the name of *T. serrata*, has been recorded as a parasite of man by Vital (1874), who records, in effect, two cases. One was a case of intestinal taeniasis in a native Algerian, reported under the paragraph heading (translated) Two taenias in the digestive tract, one of which has the appearance of *Taenia serrata*. These tapeworms were collected post mortem. He states that one tapeworm was undoubtedly *T. solium*. The other was 1 meter long and 6 mm. broad, the segments attached in such fashion as to present a saw-toothed aspect. The thick rostrum was armed with hooks, and a single lateral genital pore was noted in the segments. There are no further data on this case.

A footnote reference states that *T. serrata* has recently been collected at Constantine (the locality for Vital's case also) in company with two specimens of *T. saginata* from a young woman by the use of pumpkin-seed as a vermifuge. Parenthetically, he remarks that the worms were examined by Dr. Cauvet. Two months later, Cauvet published in the same journal (*Gazette médicale de Paris*) a note on the tapeworms found in Algeria. In this note he lists and discusses *Bothriocephalus*, *T. solium* and *T. saginata*. He says nothing whatever about *T. serrata*, and it seems safe to assume that any statements he may have made regarding a worm from man being *T. serrata* were not based on careful examination and were not intended for publication.

It is quite impossible to identify *T. serrata* by any such casual method as Vital used. Parasitologists who have mentioned Vital's cases have regularly regarded them as doubtful or erroneous. Moniez (1896) states that neither Vital nor Cauvet can be considered as authorities. He adds that he has fed *Cysticercus pisiformis* to two volunteer human subjects without developing the tapeworm. Galli-Valerio (1898) states that he once ingested six of these larvae. This occasioned a slight stomachache that night, possibly due to toxins in the



cysticerci, but no tapeworm development was noted in spite of fecal examination and the use of male fern as a vermifuge. During the summer of 1913 I ingested three *Cysticercus pisiformis* collected from a freshly killed rabbit. I did not ingest any of the cyst fluid and had no discomfort. There have been no indications of tapeworm development.

In view of the fact that ingestion of *Cysticercus pisiformis* by four persons has not resulted in tapeworm development in any case, and that Vital's and Cauvet's records show obvious evidence that there were no grounds for Vital's statement, it seems evident that his record of *T. pisiformis* should be distinctly characterized as erroneous.

*Multiceps serialis* has never been claimed as a parasite of man. Galli-Valerio (1909) states that he has eaten two larval scolices, and I recorded in 1910 the eating of three such scolices. No tapeworms developed in either case, indicating that the parasite will never be found as an accidental parasite of man. In passing, it may be said that on the face of it there would seem to be more likelihood of this parasite, which is frequently imbedded in the connective tissues in the edible musculature of the rabbit, functioning as a parasite of man than there is in the case of *T. pisiformis* where the fully developed larva is found among the inedible viscera.

*Taenia teniaeformis* has never been recorded as a parasite of man, but Krabbe (1880) has called attention to the fact that in Jutland, mice are sometimes chopped up, spread on bread and eaten raw as a folk remedy for retention of urine, and has suggested that this might lead to infestation with the adult worm. Moniez (1896) states that he has fed *Cysticercus fasciolaris* to his two volunteer subjects noted above without producing the adult tapeworm.

*Taenia krabbei* is another carnivore tapeworm that has not been reported from man, though its occurrence in the edible meat of an important food animal would indicate the likelihood of its occurring in man. However, Moniez (1896) states that his volunteers have ingested the larvae of this tapeworm without results.

*Taenia tenella* was surmised by Cobbold to be a human tapeworm arising from *Cysticercus ovis* in the meat of sheep. Railliet (1885) notes that Chatin has on several occasions ingested *Cysticercus ovis* without giving rise to a tapeworm, and Ransom (1913) states that he has ingested ten of these larvae without result. The tapeworm produced by feeding *Cysticercus ovis* to dogs was considered by Chatin to be *T. hydatigena*, but Ransom (1913) has shown that it is a distinct species of carnivore tapeworm, *Taenia ovis*. The fact that *Taenia ovis* and *Taenia krabbei*, both with larvae situated in the edible musculature of important food animals, seem incapable of developing in man, is a

further argument against the likelihood of such a tapeworm as *T. pisiformis*, with larvae in the inedible viscera, developing to an adult tapeworm in man.

*Taenia hydatigena* and *Multiceps multiceps* have never been reported as intestinal parasites of man. This is not surprising, in view of the size of the larvae and site of infection for the larvae. It is further likely that if they were present the former would be taken for *T. solium* and the latter for the more common *T. pisiformis*. I have found no records of the ingestion of the larvae by man, but Stiles (1898) states of the larvae of *T. hydatigena*, "Although several authors have attempted to infect themselves with tapeworms by swallowing this larvae, all such attempts have been negative."

The facts noted above indicate the correctness of the generally accepted view, that adult cestodes of the genus *Taenia* occurring in carnivores do not occur in man. The converse of this proposition is also true.

# A PECULIAR MORPHOLOGIC DEVELOPMENT OF AN EGG OF THE GENUS *TROPIDOCERCA* AND ITS PROBABLE SIGNIFICANCE

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The accompanying drawing represents the egg of a species of *Tropidocerca* from the proventriculus of an American woodcock (*Philohela minor*) shot at Bowie, Md., Nov. 11, 1912. A comparison of the specimens found, with the different species descriptions, shows that the specimens belong in all probability to an undescribed species, but as no male worms were recovered it is considered inadvisable to publish a specific description until more material can be collected.

The drawing is presented to show the peculiar filiform appendages projecting from either pole, a feature not only undescribed in any of the species of this genus, but, as far as the writer is aware, unique in the literature of nematodes.\* The appendages consist of a cluster of seventeen to twenty-three filaments at either pole of the egg. Most of these are not over half the length of the egg, but one or two at either pole are over twice as long.

One of the distinguishing characteristics of the trematode family, Notocotylidae, is the fact that the eggs are provided with a single long filament at either pole. To judge from the drawing of an egg of *Notocotyle quinqueseriale* Barker and Laughlin (1911), these filaments are simple prolongations of the chitinous shell. This is certainly the case in the genus *Microcotyle*, certain species of which have similar filaments, as MacCallum (1913) has seen these filaments in the process of formation from the shell. The filaments of *Tropidocerca* are, however, apparently of a different nature, and are undoubtedly formed in a different manner.

In examining a number of *Tropidocerca* eggs removed from a ruptured uterus, it was observed that only those eggs which contained fully developed embryos and which were in a position to pass through the vagina, were equipped with these filaments. Less mature eggs had perfectly smooth shells, as with most nematodes. It is obvious, there-

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\* Since this note was submitted for publication an article has appeared by Seurat (Compt. rend. Soc. de Biol. v. 76, 15 mai 1914) describing *Tropidocerca novelli* n. sp. which is characterized by similar appendages attached to the poles of the embryonated eggs. Seurat points out that similar appendages were observed by Kölliker on the eggs of *Ascaris dentata*, and by Lieberkühn in his *Tropidocerca fissispina*. Lieberkühn, failing to find this feature on all the eggs, considered it merely as an individual anomaly.

fore, that the filaments are not simple prolongations of the chitinous shell, but are added after the egg-shell is complete. This is also apparent from the figure in which the egg-shell is seen to form a complete ellipse, to the surface of which the filaments are attached.

Leuckart (1867) has shown that the albuminous covering of the eggs of *Ascaris lumbricoides* is deposited after the chitinous shell is complete, and the mamillations of this covering and the fact that it appears only on completely formed eggs suggest an analogy with these filiform appendages.

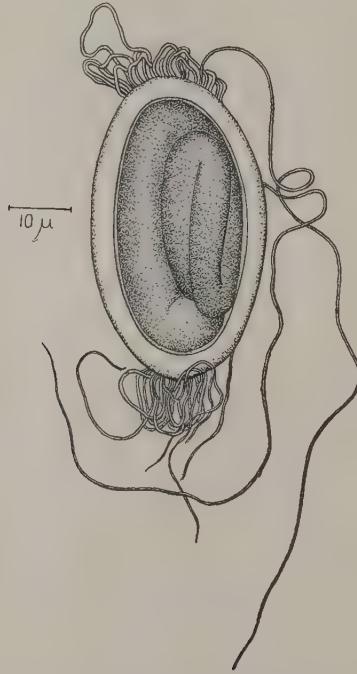


Fig. 1.—Egg of *Tropidocerca* sp., showing masses of filaments projecting from either pole.

In one of the specimens of *Tropidocerca* sp. examined by the writer, which had been pressed under a cover-glass, a number of eggs attached at their poles by the entangling of their filaments, were seen to be forced through a rupture in the uterus. It would appear, therefore, that these filaments are for the purpose of causing a number of eggs to cling together, thereby increasing the chances of infestation in the host. It is suggested by von Linstow (1879) that the eggs of the



genus *Tropidocerca* require an intermediate host. He bases his opinion on the relative thickness of the shell, the great number of eggs in a single female and their similarity to the eggs of the genus *Filaria*. If the life cycle is indirect, it would appear decidedly advantageous for the parasite that the intermediate host should be heavily parasitized, since in this way the handicap of an indirect life cycle would be lessened.

The eggs of different groups of parasites are not infrequently provided with means for furthering their life cycle. These devices are either to enable the egg to remain on its host in the case of ectoparasites, or to insure a heavy infestation of the host in the case of endoparasites. Among the former may be mentioned the long filamentous hooklets which enable the egg of the genus *Menopon* to fasten in the feathers of the host, and the method of glueing the eggs of *Haematopinus* to the hairs of its host. As a method of insuring a heavy infestation of the host in endoparasites may be mentioned the egg sacs of the cestode genus *Davainea* and the strings of eggs oviposited by *Strongyloides ovocinctus*. In this case, as described by Ransom (1911), "the eggs passing out of the vulva lodge beneath an outer cuticular layer, which, when finally shed by the worm, is transformed into elongated egg-sacs, each containing from half a dozen to fifty or more eggs." A still closer analogy to the filamentous appendages shown is seen in the mamillated albuminous covering of *Ascaris lumbricoides*, which, as Blanchard (1888) has observed, sometimes causes the eggs to adhere to one another at the poles, exactly as was observed in the case of *Tropidocerca*.

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## THE ACTION OF ARSENICAL DIPS IN PREVENTING TICK INFESTATION

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During the summer of 1912 the writer conducted experiments relating to the action of arsenical dips in preventing cattle from becoming infested with cattle ticks. The data obtained at that time were published in Bulletin 167 of the Bureau of Animal Industry. The results showed that cattle dipped in an arsenical dip are protected for two full days from becoming infested with seed ticks, but not for five days. During the past summer experiments were undertaken to determine what protection, if any, such dipping offers for a period of three and of four days, and whether there is any mortality of ticks applied to and maturing on immune animals that have been subjected to a number of dippings at intervals of one and two weeks.

The dip employed was the usual arsenical dip used in this country in the tick eradication work in the South, containing 8 pounds of white arsenic to 500 gallons of dip, with the exception that the pine tar was omitted in order to exclude the possibility of the tar playing any part in the results by exercising a repellent action on the ticks.

Two experiments were carried out. In Experiment No. 1 cattle were exposed to infestation on the third and fourth days after dipping. Six calves non-immune to Texas fever were divided into three lots of two each. In the case of Lot No. 1 seed ticks were applied three days after dipping, and in the case of Lot No. 2 four days after dipping. Lot No. 3 was not dipped and served as a control. Seed ticks were applied to this lot on the same date as to Lot No. 1. After the seed ticks were applied the different lots were placed in separate paddocks which they occupied until the close of the experiment.

As a result of this experiment it was determined that animals dipped once in an arsenical dip containing sodium arsenite equivalent to 0.1863 per cent.  $\text{As}_2\text{O}_3$  were not protected from infestation when ticks were applied three days (Lot No. 1) and four days (Lot No. 2) after dipping. It was found, however, that the infestation of the dipped animals was light, whereas that of the two controls was heavy. It would therefore appear that dipping reduced markedly the degree of infestation. Since practically no dead nymphs were observed on the animals, it is evident that the lighter infestation of the dipped animals must have been brought about by an action on the larval stage,

which, as demonstrated in last year's experiments (Bulletin 157, Bureau of Animal Industry), is in the nature of a destructive action.

This experiment completes the work of last year, which demonstrated that cattle dipped in an arsenical dip such as used in this experiment are protected for two days, but not for five days, from infestation. The present experiment shows that the toxic action of the arsenic on and in the skin of dipped cattle is still effective to a certain degree on the third and the fourth day after dipping.

In Experiment No. 2 ticks were applied to animals five days after the last of four dippings at intervals of two weeks and of one week. This experiment was conducted primarily for the purpose of determining whether ticks that mature on animals that have been regularly dipped show any mortality after dropping off, due to arsenic absorbed from the skin of the animal.

Six immune calves divided into three lots of two each were used. Lot No. 1 was dipped four times at intervals of two weeks, Lot No. 2 four times at intervals of one week and Lot No. 3 remained undipped as a control. All the calves had ticks applied to them five days after the last dipping.

In the case of Lot No. 1, one of the calves acquired a heavy, the other a light infestation; whereas, in Lot No. 2, in which the animals were dipped at intervals but half as long, the animals became only very lightly infested. In the control (Lot No. 3) both animals became heavily infested with ticks. It is therefore seen that dipping animals four times at intervals of one and of two weeks will not protect them from becoming infested when ticks are applied five days after the last dipping. The degree of infestation did not appear to be reduced in the case of the animals dipped at intervals of two weeks (Lot No. 1), but in the case of those dipped at intervals of one week the infestation was reduced to a very marked extent. It is therefore seen that when the interval between dippings is two weeks there is no increment in the toxicity of the skin of cattle, whereas when the interval is one week there is an accumulation of arsenic from previous dippings sufficient to destroy some ticks and thus reduce the degree of infestation.

Large numbers of engorged ticks were collected from the dipped and the control animals and kept in the laboratory in Petri dishes. Observations were made on these with regard to mortality, oviposition, number of eggs deposited and the percentage of eggs hatching. It was found by comparison with the controls that the ticks from the dipped animals manifested no abnormality. In other words, it may be said that ticks placed on animals five days after the last of four dippings, at intervals of one week and of two weeks, and permitted to engorge show no indication of arsenical poisoning.

## EO RHYNCHUS: A PROPOSED NEW NAME FOR NEO- RHYNCHUS HAMANN PREOCCUPIED \*

H. J. VAN CLEAVE

The genus *Neorhynchus* was founded in 1892 by Hamann to include *Echinorhynchus rutili* Müller and *Echinorhynchus agilis* Rudolphi. Practically all investigators dealing with the Acanthocephala since that date have accepted this generic name. Recently attention has been called to the fact that the name *Neorhynchus* is preoccupied. Sclater, in 1869, and, again, Milne Edwards, in 1879, employed it for other groups. In accordance with the laws of nomenclature, it then becomes necessary to reject the name *Neorhynchus* as applied to Hamann's genus. I propose the name *Eorhynchus* to designate these forms. While all other investigators dealing with this genus have been limited to a study of the two original species, it has been my good fortune to include five additional species in a comparative study, the results of which have led me to a restatement of its essential characteristics. As pointed out in an earlier paper (1913), I consider the following points as diagnostic for this genus of *Acanthocephala*:

1. Six giant nuclei in the subcuticula arranged, normally, five in the middorsal line of the body and one in the midventral line.
2. Two giant nuclei in one lemniscus and only one in the other.
3. Proboscis receptacle with but a single muscle layer in its wall.

In the light of this analysis, the contentions of de Marval (1904: 582) and of Monticelli (1905: 217), that *Apororhynchus hemignathi* Shipley should be included in this genus are based on an inadequate understanding of its natural limits.

Shipley, in his description of *A. hemignathi* (1896: 210), wrote: "As in *Neorhynchus*, the number of nuclei is very small, some twelve to twenty seem to suffice for the whole subcuticle, and perhaps two to four for each lemniscus. The nuclei are scattered about in a most irregular fashion. . . ."

I have shown (1913) that not alone the *presence* of giant nuclei, but more strikingly their *number* and *arrangement* furnish a sure criterion for the determination of members of this genus. Shipley's genus *Apororhynchus*, because of its radical departure from the typical structure of the *Eorhynchi*, cannot be included within the genus *Eorhynchus*. The valid species of this genus are, then, *Eo. rutili* (Müller

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\* Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 32.



1784), *Eo. agilis* (Rudolphi 1819), *Eo. emydis* (Leidy 1852), *Eo. gracilisensis* (Van Cleave 1913), *Eo. longirostris* (Van Cleave 1913), *Eo. cylindratus* (Van Cleave 1913) and *Eo. tenellus* (Van Cleave 1913).

Hamann (1892) also created the family Neorhynchidae for the single genus *Neorhynchus*. Porta (1907:409) accepted Hamann's revision of the Acanthocephala only in part, recognizing but two families, Echinorhynchidae and Gigantorhynchidae, and included *Neorhynchus* under the former. The characteristics already listed as diagnostic for the genus *Eorhynchus*, together with the complete fusion of the cement glands, are such essential features that the inclusion of *Eorhynchus* in the same family with *Echinorhynchus* would so distort our conception of the family Echinorhynchidae that it would cease to be a natural division of the Acanthocephala, and would become a purely artificial assemblage. In view of these facts I consider that the evidence fully justifies the retention of the family rank originally attributed to these forms for which the family name now becomes Eorhynchidae.

The writer's extensive studies on the cytology of the Eorhynchidae furnish conclusive evidence in support of the foregoing arguments. These studies in detail appear in the June number of the *Journal of Morphology*.

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## SOCIETY PROCEEDINGS

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### THE HELMINTHOLOGICAL SOCIETY OF WASHINGTON

The sixteenth regular meeting of the society was held at the residence of Dr. Ransom, Dec. 18, 1913, Dr. Ransom acting as host and Dr. Graybill as chairman.

A letter from Mrs. Elise Huber, announcing the death of her husband, Dr. J. Ch. Huber, a foreign corresponding member of the society, was read and the secretary instructed to reply, conveying the society's regrets.

The following papers were read: Notes on Sarcosporidia, by Mr. Crawley; The Ingestion by Man of *Cysticerci* of Carnivore Tapeworms, by Mr. Hall; Variations in the Eggs of *Ascaris*, by Mr. Foster; The Effect of Refrigeration on Trichina, by Dr. Ransom; and The Effect of Arsenical Dips on Ticks, by Dr. Graybill.

MAURICE C. HALL, *Secretary*.

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The seventeenth regular meeting of the society was held at the residence of Mr. Hall, Jan. 22, 1914, Mr. Hall acting as host and Dr. Ransom as chairman.

Mr. Crawley gave a review of Calkins' paper on the cultivation of amoebae.

Mr. Foster exhibited some drawings of the eggs of *Tropisurus* and presented a note in regard to them.

Dr. Hassall called attention to the index of Castellani and Chalmers latest edition of Tropical Medicine, noting the fact that it had been very poorly constructed and introduced a number of synonyms.

Dr. Cobb presented a note on the crystalline inclusions in the intestinal cells of *Rhabditis* and other free-living nematodes, and demonstrated these inclusions.

Mr. Hall presented a note proposing a new genus for *Distoma tricolor* Stiles and Hassall 1894.

Dr. Ransom presented a paper on the refrigeration of beef infested with beef measles.

MAURICE C. HALL, *Secretary*.

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The eighteenth regular meeting of the society was held at the residence of Mr. Crawley, March 12, 1914, Mr. Crawley acting as host and Dr. Graybill as chairman.

Mr. Hall presented a paper entitled An Unusual Case of Fatal Poisoning from the Administration of Male Fern as a Vermifuge.

Mr. Crawley presented a paper entitled Early Stages in the Life History of *Sarcocystis muris*.

MAURICE C. HALL, *Secretary*.

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The nineteenth regular meeting of the society was held at the residence of Mr. Foster, April 14, 1914, Mr. Foster acting as host and Dr. Cobb as chairman. Dr. Georgina Sweet and Miss Frieda Cobb were the guests of the society.

Dr. Ransom presented a paper entitled The Occurrence of a Fly Larva in the Heart of a Hog.

Mr. Hall presented a paper entitled A New Genus of Discodrilids, with a Key to the North American Species.

Mr. Foster presented a paper entitled The Specific Characteristics of *Metastrongylus apri* and *M. brevivaginus*.

Dr. Cobb exhibited and discussed his recent publication entitled Antarctic Marine Free-Living Nematodes of the Shackleton Expedition; Contributions to a science of nematology. This paper is published by the author as a tribute to Shackleton. The excellent illustrations are by Miss Frieda Cobb, a limited number of copies being hand colored, and the very striking cover-design is by Mr. Chambers. The publication bears the stamp of that individuality which is so characteristic of Dr. Cobb's papers.

MAURICE C. HALL, *Secretary*.

The twentieth regular meeting of the society was held at the residence of Dr. Cobb, May 12, 1914, Dr. Cobb acting as host and Dr. Ransom as chairman.

Mr. Hall presented a paper entitled The Superfamilies of the Parasitic Nematodes.

Mr. Foster presented a triradiate specimen of *Taenia pisiformis* and some cross sections of the worm, which was collected from a dog imported from Europe and held in quarantine at Athenia, N. J. The specimen is therefore European and not American.

Dr. Ransom presented a note on the relation of parasitic worms, especially nematodes, to cancer, and called attention to his description of *Agamone-matodum gaylordi*, recently published in a Fisheries Bulletin entitled Carcinoma of the Thyroid in the Salmonoid Fishes, by Gaylord and Marsh. There seems to be very good evidence that the nematode may act at times as an inoculating agent in the production of carcinoma.

Dr. Cobb exhibited to the society specimens representing twenty-seven new genera of free-living nematodes and pointed out various peculiarities in connection with the annulation, mouth parts, spicules, spermatozoa and nutritional granules.

MAURICE C. HALL, *Secretary*.



# NOTES

## HELMINTHOLOGIC INVESTIGATIONS

The departure of the expedition, under the direction of Dr. R. T. Leiper, Helminthologist of the London School of Tropical Medicine, to the Eastern Tropics, is an event which must prove of considerable scientific importance. Accompanying Dr. Leiper is a medical officer seconded by the admiralty, Surgeon E. L. Atkinson, R.N., who, since his return from the Scott Antarctic Expedition, has been working at the London School of Tropical Medicine on pathologic specimens he brought back from South Polar regions. The personnel of the expedition is further perfected by the presence of a zoologist, Mr. A. Cherry-Garrard, who served as assistant zoologist in the late Antarctic Expedition. The funds necessary for the investigation have been found partly from the bequest of the late Lord Wandsworth to, and now under the control of, the London School of Tropical Medicine, and partly they have been contributed to by the Tropical Disease Research Fund of the Colonial Office.

The primary object of the expedition is to ascertain the mode of spread of the trematode diseases of man.

Facilities for investigation have been afforded by several countries, and in Sumatra the United States Rubber Company have specially invited the expeditionary party to study the helminths as they affect the workmen on their rubber estates.

In a previous leader in this journal we drew attention to the solidarity of scientific investigation, citing as an instance the bearing Arctic and Antarctic pathologic and zoologic findings had on our geographical knowledge of the spread of disease, and of the limitations or otherwise of pathologic germs by heat and cold. The association of experts with a first-hand knowledge of these subjects in the frigid zones is of particular interest on the occasion of this the most recent scientific expedition to the Tropics.

The intestinal parasites met with in man in the Tropics might well be termed legion, and no medical practitioner who deals with tropical ailments at home or abroad can afford to do aught as a first and stereotype item of practice but to administer an anthelmintic, or at least a simple purge, so as to ensure that there is no worm or its ova complicating the symptoms of any of the intestinal derangements that may come to him for treatment. How often even the most skilful doctor in the Tropics has had cause to repent the non-observance of this practical axiom. Intestinal fluxes ascribed to dysentery, acute, chronic or intermittent sometimes prove intractable to the customary remedies for dysenteric lesions, and the cause of the resistance to their action is not detected until the patient goes to another doctor, who, administering an anthelmintic, clears up the mystery, to the chagrin of the aforesaid and the loosening of the unflattering tongue of the sufferer. Apart, however, from the mere clinical aspect of the good this expedition may do, there are larger and more important factors to be considered, namely, the public health and the commercial points of view. These are intimately associated. The good health of the workers in a mine, on a rubber, tea or coffee plantation, or on any commercial undertaking where men are employed in large numbers, affects the commercial value of the undertaking they are engaged on to the extent that it may have to be abandoned by the capitalist owing to the monetary losses ill-health entails. Such a state of things affects the whole world by the fact that many necessary articles of food become dearer not only locally, but universally, and the tea, coffee, cocoa, sugar, rice, tapioca, sago, etc., of our ordinary diet is enhanced in price. Thirdly, the scientific advance likely to ensue from the expedition may be hoped to be great and lasting. The men engaged on it have a high scientific reputation and their work is sure to be sound and reliable. It is to be hoped that our knowledge of bilharziosis will be advanced, that ankylostomiasis will be rendered more capable of being controlled, and that the flora of the intestine generally will be placed on a surer footing than obtains at present.—*Journal of Tropical Medicine and Hygiene*, March 16, 1914.